SYNOPSIS OF RESEARCH PROJECT

ON

SUCCESSION, MECHANISM OF RESISTANCE AND MANAGEMENT OF SOIL ARTHROPODS IN GROUNDNUT

UNDER THE GUIDANCE OF

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SYNOPSIS OF RESEARCH PROJECT

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9. Introduction

Groundnut [*Arachis hypogaea* (L.)] belonging to the family Fabaceae, sub-family Faboideae, the cultivated groundnut has a basic chromosomal number (x) of 10 and is an allotetraploid (2n = 40). Also called goobers, earth nuts, pea nuts, pindas, manilla nuts and monkey nuts. Another name for it is "King of Oil Seed." It grows in a variety of soil types and climates in numerous Indian states. However, medium black sandy loam with appropriate drainage conditions is the most advantageous. The crop may be effectively produced in regions with 600-1250 mm of precipitation and it is a significant oilseed crop that is cultivated in tropical and subtropical areas all over the world. A significant supply of edible oil and protein for millions of people worldwide, this oilseed crop is widely grown in many agro-ecological zones (Kumar and Bhattacharya, 2019). Its oil is mostly used to manufacture vanaspati ghee, or vegetable oil. Groundnut seeds contain about 26% protein and 45% oil. Almost all tropical and subtropical countries in the world produce a significant portion of groundnuts (Gocher *et al*., 2020).

It is the world's thirteenth-largest food crop, the fourth most significant oilseed and the largest source of edible oil. About 30% of India's whole supply of oil comes

from this crop, this is among the most crucial oil seed crops grown. In rainfed regions, groundnuts are the main crop grown by resource-constrained Indian farmers (Dahiphale *et al*., 2022).

High in fibre, protein, healthy fats, polyphenols, flavonoids, phytosterols and other minerals, groundnuts promote a balanced diet and reduce the risk of long-term diseases like diabetes and heart disease (Muthayya *et al*., 2020). Outside of human nutrition, groundnuts are utilised in a variety of industries. A valuable raw ingredient for industrial processes, cosmetics and the manufacturing of edible oil is groundnut oil. Additionally, biomass energy, animal feed and even biofuels have been made from groundnut residues like shells and haulms (Huang *et al*., 2021).

Groundnut oil is used to manufacture soap, cosmetics, lubricants, olein, stearin and their salts in addition to being edible (Himal, 2009). Groundnuts are useful for treating diarrhoea, stomatitis and haemophilia. Additionally, they might lessen malnutrition in children. The meal is beneficial for growing children, nursing mothers and pregnant women (Kenny and Finn, 2004). Additionally, it is an excellent supplier of niacin, which promotes brain and blood flow.

For every 100 grammes of seed, the kernels provide 18% carbohydrates, 47–53% oil, 26 mg calcium, 401 mg phosphorus and 2.1 mg iron. Additionally, they have 17.2 mg of niacin, 0.13 mg of vitamin B2 (riboflavin) and 1.14 mg of vitamin B1 (thiamine). It contains 5.6 calories per gramme. It produces income in addition to being a major source of dietary fats and protein (Padgham *et al*., 1990; Dodiya *et al*., 2023). Additionally, it contains 20–50% protein, 10–20% carbs, 40–50% fat and up to 50% non-drying oil (Mehta, 2002).

Groundnut kernels are used in food preparations like chocolate, peanut butter and peanut milk in addition to being consumed raw, roasted, fried or boiling. Groundnut oil is edible and contains oleic and linoleic acids. In addition to manure, groundnut cake and its straws/haulms are used as cow feed because they provide 7%–8% nitrogen, 1.5% phosphorus and 1.2% potassium. Its shell is used as fuel and to make coarse boards, cork substitutes, *etc*. Because they have symbiotic bacteria on their roots that fix nitrogen, groundnuts are a soil-enriching crop that is suitable for crop rotation.

Because of their varied applications, groundnuts are an excellent source of income for both home and foreign markets in many established and developing nations. In addition to being a superior source of animal feed, groundnuts provide about half of

the 13 essential vitamins and 7 of the 20 critical minerals required for human growth and development.

Groundnuts have a vital ecological role in the development of sustainable agricultural systems additionally to providing for people's nutritional needs. It improves soil fertility and reduces dependency on synthetic nitrogen fertilisers by fixing nitrogen through synthesis with Rhizobium bacteria in root nodules (Mahmud *et al*., 2020; Sapalina *et al*., 2022). In addition to supporting the diversification of food production, its rich nutritious content which includes protein, vegetable oil, fibre, vitamin E, folic acid, magnesium and antioxidants that are beneficial to human health also has a high economic value (Wahyudi *et al*., 2019; Kasim *et al*., 2024).

India, one of the top producers of groundnuts worldwide, produced 10.41 million tonnes of groundnuts in 2025 on 5.05 million hectares of land with a productivity of 2080 kg/ha (Anon., 2025a). In India mainly 90 percentage of groundnut area occupying by Southern and Western states like Gujrat, Andhra Pradesh, Tamil Nadu, Rajasthan, Karnataka, Maharashtra and Madhya Pradesh together. In India, Gujarat has the largest share in terms of area and production. In Gujarat, the area under groundnut cultivation is 19.60 lakh hectares, with a yearly output of 52.20 lakh tonnes and a productivity of 2656 kg/ha (Anon., 2025b). The major groundnut-growing districts in Gujarat are located in the Saurashtra region, including Junagadh, Jamnagar, Amreli, Rajkot, Gir-Somnath and Devbhoomi Dwarika.

Among numerous biotic and abiotic factors that lead to low groundnut yield, Insect infestations are acknowledged as one of the primary barriers to groundnut production, causing large losses in India (Singh, 1980). The only factor contributing to 10-20% crop loss and 10-25% post-harvest loss of groundnut output in India is insect pest infestation; long-term storage also causes the worst losses. Insect pests are among them significant limiting factor that results in significant crop losses in underdeveloped nations. The adoption of poor management practices, such as excessive pesticide use, inadequate crop rotation and unfavourable storage conditions, is one of the primary drivers of pest outbreaks (Joshi, 2020). Pests have a detrimental effect on both human health and crop productivity (Tandi *et al*., 2014; Misca *et al*., 2014 and Datcu *et al*., 2019). Farmers worldwide are estimated to spend more than $10 billion a year on insect-pest control (Van Lenteren, 2005).

The groundnut crop is impacted by a variety of pests, which raise production costs and reduce yield (Agoyi *et al*., 2019; Okello *et al*., 2013). For instance, publications

(Wightman and Amin 1988; Nataraja *et al*., 2014) stats that about 360 insect pest species attack on this crop worldwide, with certain ground-dwelling pests even causing more output losses than leaf feeders. Soil pests frequently result in significant output losses due to farmers' inability to identify their presence early enough for timely control (Wightman and Amin 1988). The main insect pests are listed below.

1. Hairy caterpillar - *Spilarctia obliqua* (Walker)
2. Leaf eating caterpillar - *Spodoptera litura* (Fabricius)
3. Pod borer - *Helicoverpa armigera* (Hubner)
4. White grub - *Holotrichia consanguinea* (Hope)
5. Whitefly - *Bemisia tabaci* (Gennadius)
6. Leaf miner - *Aproaerema modicella* (Deventer)
7. Thrips - *Scirtothrips dorsalis* (Dist)
8. Aphid - *Aphis craccivora* (Koch)
9. Jassid - *Empoasca kerri* (Pruthi)
10. Earwig - *Euborellia stali* (De geer)
11. Termite - *Odontotermes obesus* (Rambur)
12. Wireworm - *Lanelater fuscipes* (Fabricius)

Additionally, other pests like birds, squirrels, rodents, partridges, centipedes, larger cane rats, red ants, monkeys, snails and sheep have a major influence on groundnuts (Loko *et al*., 2019).

Among them the soil arthropod pests, white grub (*Holotrichia consanguinea*), termite (*Odontotermes obesus*), millipedes (*peridontopyge* spp.), wireworms (*Heteroligus claudius*) and earwig (*Euborellia stali*) are major constraints to peanut. One of the five pests of national importance in India, white grubs seriously hinder the production of many annual crops, such as groundnuts, pearl millet, sorghum, cowpea, pigeonpea, greengram, clusterbean and chilli, as well as perennial crops, such as sugarcane, tea, coffee and arecanut. Wireworms are another extremely harmful soil-dwelling pest of horticultural and agricultural crops which are the click beetle larvae (Coleoptera: Elateridae). Sugarcane, maize, groundnuts, potatoes, wheat, sorghum, onions, ginger, chilly, sugar beetroot, carrots and soft roots are just a few of the many crops they eat. They damage early seedlings and germinating seeds by feeding on roots and burrowing through lower stem parts and root crops.

A colony of termites can have workers, soldiers, reproductive queens, and kings, are present. (Watson *et al*., 1983). It has been demonstrated that termites cause up to

30% of groundnut pods to be scarified, 30–40% of pods to be destroyed and 25–100% of groundnut plants to perish from damaged roots (Anon., 2013).

10. Practical Utility of the Research Project

Gujarat's Saurashtra area has seen a steady growth in groundnut, which has resulted in a rise in the number of different soil-dwelling arthropods. In the Saurashtra region, groundnut has been increasingly important in recent years, particularly in subhumid land areas where the incidence of soil arthropods is relatively higher. Farmers can take prompt management actions since the succession of key pests in groundnut crops indicates their status and periods of maximal activity.

Because of their indirect effects on pods, soil arthropods are among the primary reasons of groundnut yield loss and oil quality. Therefore, the current study will concentrate on utilising biopesticides products for the administration of soil-inhabiting arthropods since they provide a safe, effective and sustainable method of controlling the pest while maintaining soil health, farmer welfare and biodiversity.

Another is that one of most well-known methods for controlling soil arthropods that negatively impact groundnut output is the use of insecticides. Adopting more recent pesticides with unique modes of action that are safe for the environment and selective is becoming more and more necessary to address these issues. In order to achieve sustainable control of the soil arthropods in a practical, affordable and environmentally friendly way, use of organic amendment-enriched entomopathogenic fungi which help to conserve soil biodiversity. Therefore, in order to manage soil arthropod pests in a sustainable and ecologically friendly way, finding groundnut cultivars that are both extremely productive and resistant to soil arthropods.

Keeping these facts in view, the study entitled **"Succession, mechanism of resistance and management of soil arthropods in groundnut"** is proposed with following objectives.

11. Objectives

1. To study the succession of soil arthropods in groundnut
2. To evaluate the efficacy of different biopesticides against soil arthropods
3. To evaluate the efficacy of different insecticides against soil arthropods
4. To evaluate the entomopathogenic fungi enriched with organic amendments against soil arthropods
5. To study the biochemical basis of resistance in different groundnut varieties/cultivars about infestation of soil arthropods

12. Review of Literature

Attempts were made to review the available literature on the studies undertaken. For the sake of convenience, it has been divided under the following heading:

12.1 Succession of soil arthropods in groundnut

Desai and Patel (1965) reported that the mile incidence of white grub as major pest of groundnut and it was found active after the first monsoon rain of the season. They also noticed that the significant damage in groundnut at first week of July nearly 24.90 per cent plant mortality in growing districts *viz.,* Amreli, Bhavnagar and Mahesana of Gujarat.

Rai *et al.* (1969) recorded that the emergence of beetle of *H. consanguinea* take place in month of June ends, but egg laying begins in July month. Pupa formation starts in October month and the duration of pupal stage was about a fortnight. Adult are formed in November month and remain in soil till they emerge in month of June next year.

Brar and Sandhu (1982) noticed that adult emergence of *H. consanguinea* in the second two weeks of June when it rained (26.2- 34.0 mm) and the temperature was 29-30 ^{0}C and the relative humidity was 70-72 per cent. Adult emerged between 19.45 and 20.00 hour and entered the soil in next morning at about 05.30 hour; this was continued for 27-35 days.

Yadav (2017) reported that peak incidence of white grub was observed in 29th and 26th SMW during *kharif* 2014 and 2015, respectively. Neem tree was discovered to be the most preferred host by adult of *H. consanguinea* during present study period. The highest grub density in soil and plant mortality was recorded in the second fortnight of October and first fortnight to October during *kharif* 2014 and 2015, respectively

Gite *et al.* (2015) revealed that the population was 2.72 grubs/m^2 in the first two weeks of May, which corresponds to the 19th SMW. After May, the grub's population grows. The second two weeks of September had the largest grub population (6.90 grubs/m^2), which corresponds to the 38th SMW. According to the connection, there was a highly substantial negative link between the number of white grubs and both temperature and rainfall. Additionally, there was a strong positive correlation between the grub population and relative humidity.

Milosavljevic *et al.* (2017) found that the two wireworm species, *Limonius californicus* and *L. infuscatus*, were most prevalent in the wheat crop relatively early in the season, and that the total number of wireworms captured in soil cores decreased as

the season went on. Both species' larvae were mostly found in the top 70 cm of the soil profile, indicating that they mostly consume seeds and plant roots down to this depth. Although the two species' seasonal abundance patterns were comparable, there were notable differences in their eating habits. The findings show that *L. californicus* eats more vigorously as spring turns into summer, but *L. infus* catus activity declines as the crop season goes on.

Gohil *et al.* (2018) noted that termite activity began on the 10th SMW and persisted until the 14th SMW in the summer. During the *Kharif* season, the population ranges from the 30th to the 43rd SMW. During the summer and *kharif* seasons, the pest activity peaked on the 23rd and 40th SMW, respectively. However, there was a highly significant positive correlation between termite activity in groundnuts in both seasons and weather parameters such as evaporation, minimum, maximum, and mean temperature, soil temperature at 5 cm, 10 cm, and 15 cm depth in the afternoon, and soil temperature at 15 cm depth in the morning. In contrast, wind speed had a substantial negative correlation with termite population in groundnuts during both seasons, while morning, evening, and mean vapour pressure had a highly significant negative correlated.

12. Efficacy of different biopesticides against soil arthropods

Gohil (2013) tested the efficacy of nine organic amendments against groundnut termite and found that lowest termite population was noted in plots that were treated with neem cake (6.10/stick), castor cake (9.11/stick) and vermicompost (11.82/stick) were found equally effective in reducing the termite's population in groundnut crop. The least amount of pod damage was noted in plot treated with neem cack (2.44%) It was comparable to castor cake (6.92%).

Guo *et al.* (2013) conducted an experiment using entomopathogenic nematodes (EPNs) against white grub and found that, in comparison to chlorpyrifos and other treatments, *Steinernema longicaudum* X-7 and *Heterorhabditis bacteriophora* H06 at 10,000 and 5,000 infective juveniles (IJs) per plant contributed significantly higher percent reduction of the white grub larvae, lower percentage of the injured legume, and higher peanut yield.

Vinayaka and Patil (2018) evaluated the effectiveness of *Metarhizium anisopliae* EC formulations against white grub infesting groundnut and data revealed that *M. anisopliae* Novozyme @5×10^9 (3ml/lit) recorded 0.72 white grubs/m row and

M. anisopliae T-stanes @1×10^9 (3ml/lit) recorded 0.80 white grubs/m row. Also, treatment *M. anisopliae* (Novozyme) 5×10^9 (3 ml/l) recorded highest yield (18.00 q/ha).

Li *et al.* (2020) investigated the efficacy of *Metarhizium anisopliae* applied to the soil at five intervals and revealed that grub densities in all *M. anisopliae* treated plots were significantly less compared to the control in groundnut and also recorded highest mortality (72%) in *M. anisopliae* treatment applied at early flowering at 30 days after showing.

Visalakshi *et al.* (2020) evaluated the efficacy of biocontrol agents against termite infesting sugarcane and revealed that during field trial high germination was recorded *Metarhizium anisopliae* (58.99%), followed by *Heterorhabditis indica* (58.07%) and low in control (49.62). Low bud damage recorded low in *Metarhizium anisopliae* (40.97%), followed by *Heterorhabditis indica* (41.9%) and *Beauveria bassiana* (42.71%). Among the all-treatments lowest termite population was noted in *Metarhizium anisopliae* (11.33/pit); *Beauveria bassiana* (12.9/pit) and *Heterorhabditis indica* (15.2/pit).

Choudhary *et al.* (2023) revealed that seed treatment, as well as soil application of imidacloprid 600 FS @ 5 ml/kg + *Beauveria bassiana* 1.15 WP @ 2 kg /ha, was discovered to be particularly successful against termite with lowest (9.34% plant damage) after 110 days of chickpea sowing, followed by fipronil 5 SC @ 5 ml/ kg + *Metarrihizium anisopliae* 1.15 WP @ 2 kg/ha with (10%) and clothianidin 50 WDG @ 2 g/ kg + *Beauveria bassiana* 1.15 WP @ 2 kg /ha with (10.62%).

Seram *et al.* (2023) found that field spraying with *Metarrhizium anisopliae* (1×10^8 spores/ml @5ml/ l) was discovered to be better and recorded lowest grub incidence in groundnut (1.00 grubs/ 12 sq m plot) over *Beauveria bassiana* (1.75 grubs/ 12 sq m plot) at the same dose. Also, *M. anisopliae* (1×10^8 spores/ml @5ml/ l) recorded highest pod yield (2.684 q/ha).

Visalakshi *et al.* (2023) investigated the effectiveness of entomopathogenic fungi and nematodes against sugarcane infested with white grub and revealed that use of entomopathogenic nematode strain *Heterorhabditis indica* NBAII-H38 (12 kg a.i./ha) soil application two times at monthly interval resulted in higher reduction (81.17%) of white grub damage. Also, application of entomopathogenic fungus strain *Metarhizium anisopliae* NBAIR Ma4 (2.5 kg a.i./ha) treated plots caused higher percentage reduction (78.33%) of white grub than chlorantraniliprole (54.17) treated plot.

12.3 Efficacy of different insecticides against soil arthropods

Yadav and Ameta (2015) revealed that among the ten treatments fipronil 80 WG @ 125 g/ha recorded lowest pod damage (2.0 %) and it was comparable to flubendiamide 24% 480 SC @ 250ml/ha (2.0 %), followed by beta-cyfluthrin 9% + imidacloprid 21% 300 OD@ 175 ml/ha recorded 2.3 per cent damage.

Pandey (2016) examined the effectiveness of several granular pesticide pre-sow applications against white grub infesting rain-fed soybeans and result shows that clothianidin 50 WDG applied 0.120 kg a.i. ha^{-1} proved to be most effective by registering lowest plant mortality (*i.e.* 6.94 and 8.20%) followed by imidacloprid 70WG @ 0.30 kg a.i ha^{-1} where the plant mortality was 8.99 and 8.5 per cent during two consecutive years.

Gaur *et al*. (2017) investigated the relative effectiveness of several treatments using fungicides, insecticides, amendments, and biocontrol agents among the treatments with the lowest cumulative plant death from white grub was recorded in when used as seed dressers, the plot treated with chlorpyriphos 20 EC @ 25 ml/kg seed + *Pseudomonas maltophilia*-4 (PM-4) @ 10 ml/kg seed + captan @ 3 g/kg seed was 1.2% in 2011 and 1.5% in 2012. This was followed by imidacloprid 17.8 SL @ 7 ml/kg seed, where cumulative plant mortality was 1.8% in 2011 and 1.7% in 2012. Chlorpyriphos 20 EC + PM-4 + captan treatment had the maximum yield (20.20 q/ha in 2011 and 19.80 q/ha in 2012).

Kumar *et al*. (2020) observed that bifenthrin 10 EC @ 2 ml/kg recorded 3.04 percent damage, whereas imidacloprid 600 FS @ 3 ml/kg seed was shown to be the most effective and recorded the lowest 2.79 percent damage. Imidacloprid 600 FS (3 ml/kg) had the lowest number of termites per stick across all treatments (3.97/stick), followed by bifenthrin 10 EC (2 ml/kg) (7.49/stick).

Jakhar *et al*. (2020) evaluated a few pesticides as seed dressers to prevent white grubs in groundnut crops and results shows that among the treatments the imidacloprid 600 FS @ 6.5 ml per kg seed treatment had the lowest plant mortality (9.33%) and was noticeably better than all other treatments against white grub and highest pod yield (24.63 q/ha) followed by clothianidin 50 WDG @ 2.0 g per kg seed with (10.33%) plant mortality and (24.03 q/ha) pod yield.

Baloda *et al*. (2021) evaluated efficacy of nine insecticides in the groundnut crop against white grubs among the treatments pooled data shows that lowest Imidacloprid 17.8 SL was found to cause plant death with 12.02 per cent plant mortality Imidacloprid

600 FS comes next with (13.80%). They also recorded pod yield among the treatments maximum pod yield was recorded in imidacloprid 17.8 SL with 26.53 q/ha followed by imidacloprid 600 FS (25.99 q/ha).

Panse (2021) noted that seed treatment of clothianidin 50 WDG at 1 g a.i./kg, or quinalphos 25 EC at 5 g a.i./kg seed or imidacloprid 17.8 SL at 0.6 g a.i./kg seed and Seed furrow application of quinalphos 25 EC @ 400 g a.i./ha or imidacloprid 17.8 SL @ 48 g a.i./ha in groundnut crop effect fully management white grub into field condition. Also, Seed dressing of chlorpyriphos 6.5 ml/kg and drenching with soil insecticides like chlorpyriphos 5ml/litre of water at the localized spots give good control of termite population.

Nakrani and Sevak (2021) studied the bio-efficacy and phytotoxicity of Imidacloprid 600 FS against termite infesting groundnut and result shows that least termite damage was recorded in imidacloprid 600 FS @ 4.0 ml/kg was 6.01 per cent while maximum damage was recorded in untreated control (20.87%). The maximum pod and straw yield were recorded in imidacloprid 600 FS @ 4.0 ml/kg which was (1756 kg/ha, 3213 kg/ha) and it is also at par with imidacloprid 600 FS @ 2.0 ml/kg (1568 kg/ha, 2861 kg/ha), respectively.

Seram *et al*. (2024) tested insecticides and bioformulations against the groundnut's white grub and outcome showed that seed treatment with imidacloprid 17.8 SL @ 3ml/ kg seeds turned out to be the most effective by exhibiting the lowest grub incidence (0.17 grubs/ 12 sq m plot) and minimum plant infestation (1.82%), followed by chlorpyrifos 20 EC @ 25 ml/ kg recorded (0.33 grubs/ 12 sq m plot) and minimum plant infestation (2.32%). Also, among the treatments imidacloprid 17.8 SL @ 3ml/ kg and chlorpyrifos 20 EC @ 25 ml/ kg recorded highest pod yield was 3.472 q/ha and 3.392 q/ha, respectively.

Kumar and Pandey (2023) examined the bioefficacy of more recent pesticides against soybean white grub and revealed that fipronil 40% + imidacloprid 40% WG @ 300 g a.i./ha proved to be the most effective, with the lowest plant damage of 5.56 and 6.06%, followed by clothianidin 50 WG (120 g a.i./ha), where the plant damage was 6.06 and 7.07% in 2019 and 2020, respectively. The highest and lowest grain yields among the treatments were noted in fipronil 40% + imidacloprid 40% WG @ 300 g a.i./ha (23.33 and 24.44 q/ha) and emamectin benzoate 5 SG @ 12.5 g a.i./ha (13.33 and 15.19 q/ha) during two consecutive years of study.

Rao *et al*. (2025) found that groundnut crops treated with imidacloprid 600 FS @ 2 ml + 4 ml of water/kg seed and furrow application of carbofuran 3 G @ 33 kg/ha prior to planting had no root grub incidence or plant death. The highest pod yield recorded in plot treated with imidacloprid 600 FS @ 2 ml + 4 ml of water/kg seed was (1775 kg/ha) followed by carbofuran 3 G @ 33 kg/ha prior to planting (1698 kg/ha).

12.4 Entomopathogenic fungi enriched with organic amendments against soil arthropods

Visalakshi *et al.* (2015) showed that when sugarcane plots treated with *M. anisopliae* @ 5×10^{13} spores/ha mixed with farm yard manure (FYM) were planted, there was a 93.6% decrease in white grub damage and a 77.22% decrease in white grub population. *Beauveria bassiana* @ 5×10^{13} spores/ha mixed with FYM showed an 88.09% decrease in white grub damage and a 74.08% decrease in white grub population.

Ramanujam *et al.* (2021) evaluated the effectiveness of entomopathogenic fungus in controlling sugarcane infested with white grub and notice that soil application of *Metarhizium anisopliae* NBAIR Ma4 (1×10^{8} cfu/g) @ 2.5kg/ha in 250 kg FYM/ha recorded (90.58%) reduction over control percentage of plant damage brought on by white grubs and also recorded lowest population of white grub (1.53/10 m row length). Followed by *Beauveria bassiana* NBAIR Bb 5a (1×10^{8} cfu/g) @ 2.5kg/ha in 250 kg FYM/ha was recorded (78.88%) reduction over control in per cent plant damage with (2.20/10 m row length) white grub population.

Patel *et al.* (2022) studied the impact of organic amendments and entomopathogenic fungi on white grub and showed that applying vermicompost @ 1 ton/ha + *M. anisopliae* 1.15 WP (1×10^{8} cfu/g) @ 2 kg/ha to treatment soil resulted in the least amount of plant mortality (8.02%) with the lowest population of white grub (0.19/1 m row). This was comparable to applying castor cake @ 1 ton/ha + *M. anisopliae* 1.15 WP (1×10^{8} cfu/g) @ 2 kg/ha with a population of white grub (9.03%).

12.5 Biochemical basis of resistance in different groundnut varieties/cultivars about infestation of soil arthropods

Gohil (2013) studied relative susceptibility of ten groundnut varieties against termites, among them varieties GG-11, TG-26 and TG-37 were found superior in suppressing the termites damage and produced higher pod yield (1926 to 2130 kg/ha) and haulm (3491 to 3963 kg/ha). The groundnut varieties GG-5, GG-20, GG-7 and GJG-31 were found less susceptible against termites and recorded 1685 to 1862 kg/ha

pods and 2809 to 3317 kg/ha haulm, whereas GG-6, TPG-41 and GG-2 gave poor performance against termites.

Malik *et al.* (2015) investigate six groundnut cultivars *i.e.* Golden, BARI-2000, Australian, BARD-479, ICG-7326 and 2KCGC20 against the termite (*Odontotermes obesus*). Among the cultivars the maximum mean populations of *O. obesus* workers were recorded on 2KCGC20 (30.82 ± 2.75 workers/plot) and Australian (30.65 ± 2.92 workers/plot), followed by BARI 2000 (19.55 ± 2.51 workers/plot), Golden (17.30 ± 2.27 workers/plot) and BARD-479 (16.82 ± 2.06 workers/plot). The minimum mean population of *O. obesus* workers was found on ICG-7326 cultivars (14.85 ± 1.81) workers/plot.

Pawar (2021) screening eighty-six against earwig, wireworm and subterranean ants pod damage in groundnut. Among the eighty-six genotypes lowest earwig damage was recorded on STVT-I-2020-01 (0.00%), STVT-I-2020-07 (0.00%), HOVTSTB-I-2020-07 (0.00%) and HOVTVG-I-2020-07 (0.00%). Highest number of pods damage by earwig were recorded on TSB-I-2020-09 (16.25%), followed by ISK-I-2020-06 (15%), ISK-I-2020-29 (15%). Lowest wireworm damage was recorded on STVT-I-2020-01 (0.00%), STVT-I-2020-07 (0.00%), HOVTSTB-I2020-07 (0.00%), and HOVTVG-I-2020-07 (0.00%). Highest number of pods damage of wireworm was recorded on TSB-I-2020-09 (17.75%), followed by ISK-I-2020-29 (16.05%), ISK-I-2020-6 (16.25%). Lowest subterranean ant pod damage was recorded on STVT-I-2020-01 (0.00%), STVT-I-2020-07 (0.00%), HOVTSTB-I-2020- 07 (0.00%) and HOVTVG-I-2020-07 (0.00%), respectively, which are highly promising genotype. Highest number of pods damage of subterranean ants was recorded on IVK-I-2020-05 (16.75%) followed by ISK-I-2020-12(16.5%).

Madhavrao (2022) investigated eighty six groundnut genotypes in addition to one check LGN-1 against earwig, wireworm, subterranean ant and revealed that out of eighty six genotypes 0 per cent pod damage of earwig was recorded in the genotypes HOVTSB-I 2021-19 (0.00%) and IVK-I 2021-9 (0.00%).Whereas highest pod damage recorded in genotypes ISK-I 2021-4 (13.88%), ISK-I 2021-3 (12.84%), AVK-2021-3(12.24%), AVK-2021-2 (11.64%) and LGN-1(10.99%). Same as among the eighty six genotypes 0 per cent pod damage of wire worm recorded in genotypes HOVTSB-I 2021-19 (0.00%) and LSVT-I 2021-2(0.00%). While AVK-2021-2 (18.07%), ISK-I 2021-4 (15.68%), AVK-2021-5 (11.47%), AVK-2021-3 (11.20%) and LGN-1 (11.64%) recorded highest pod damage of wire worm. In case of subterranean ant

HOVTSB-I 2021-19 (0.00%) found no pod damage, but the most pod damage was found in genotypes ISK-I 2021 26 (12.26%), ISK-2021-10 (11.17%), AVK-2021-3(10.91%), AVK-2021-2 (10.99%) and check LGN-1 (10.91%).

13. Materials and Methods

13.1 Succession of soil arthropods in groundnut

13.1.1 Details of field experiment

1.	**Location of experiment**	:	Oilseeds Research Station, Junagadh Agricultural University, Manavadar
2.	**Season and year**	:	*Kharif*, 2026 and 2027
3.	**Crop and variety**	:	Groundnut, GG-23
4.	**Plot size**	:	7.2 m × 10 m
5.	**Spacing**	:	45.00 cm × 10.00 cm
6.	**Seed rate**	:	100 kg/ha
7.	**Fertilizer**	:	12.5:25:50 NPK kg/ha

13.1.2 Methodology

In order to study the succession of soil arthropods in groundnut, the plot will be divided in to 20 equal quadrates of size 1.00 m × 1.00 m. All the other agronomical operations will be adopted as per the recommendations. The crop under the experiment will be kept free from insecticides throughout the season. The observations on soil arthropods will be recorded from one week after germination to the harvest of the crop at weekly intervals on five randomly selected plants from each quadrate. The observation of soil arthropods will be recorded as per cent plant mortality; after harvesting, soil arthropods population will be recorded from 2 rows of one-meter area in each plot by digging soil. and natural enemies (if any) will be recorded per plant.

With a view to study the impact of different abiotic factors *viz.*, temperature [maximum (MaxT) and minimum (MinT)], relative humidity [morning (RH_1) and evening (RH_2)], bright sunshine (BSS), rainfall (RF), soil temperature and vapour pressure [morning (VP_1) and evening (VP_2)] on insect pest population, from the collected data statistical analysis will be worked out. The weekly meteorological data will be obtained from the meteorological observatory of Junagadh Agricultural University, Junagadh.

13.1.3 Observations to be recorded

1. Per cent plant mortality

2. Population of soil arthropods/1 m row

3. No. of natural enemies per plant (If any)

13.2 Efficacy of different biopesticides against soil arthropods

13.2.1 Details of the field experiment

1.	**Location of experiment**	:	Oilseeds Research Station, Junagadh Agricultural University, Manavadar
2.	**Season and year**	:	*Kharif*, 2026 and 2027
3.	**Crop and variety**	:	Groundnut, GG-23
4.	**Gross plot size**	:	2.25 m × 5.0 m
5.	**Net plot size**	:	1.35 m × 4.0 m
6.	**Spacing**	:	45.0 cm × 10.0 cm
7.	**Seed rate**	:	100 kg/ha
8.	**Fertilizer**	:	12.5: 25: 50 NPK kg/ha
9.	**Design**	:	Randomized Block Design
10.	**Treatments**	:	10
11.	**Replications**	:	3

Table 1. Treatment details of biopesticides

Treatment No.	Treatments	Spore load (cfu/g, min or POBs/ml)	Quantity required (kg or l/ha)
T_1	*Beauveria bassiana* 1.15 % WP	1 x 10^8	2.5
T_2	*Metarhizium anisopliae* 1.15 % WP	1 x 10^8	2.5
T_3	*Bacillus thuringiensis* var. *kurstaki* 1 % WP	1 x 10^8	2.5
T_4	NSKE	-	25.0
T_5	*Nomuraea rileyi* 1% WP	1 x 10^8	2.5
T_6	*Steinernema carpocapsae*	6×10^5 ij/m^2	4.0
T_7	*Heterorhabditis indica*	6×10^5ij/ m^2	4.0
T_8	Azadirachtin 10000 ppm	-	1.0
T_9	*Lecanicillium lecanii* 1.15 WP	$1x10^8$	2.5
T_{10}	Untreated Control	-	-

13.2.2 Application of biopesticides

Groundnut crop will be raised by adopting recommended agronomical practices in *Kharif*, 2026-27. Treatment wise drenching application of bio-pesticides will be given by using knapsack sprayer (15 litre capacity) in plant row. The control plots will

be drenching with water. Drenching fluid will be prepared by mixing measured quantity of water and bioagent. Drenching will be carried out, at the initiation of pest. For soil drenching treatments, 1000 lit per ha of water will be used and need based subsequent application will be done.

13.2.3 Method of recording observations

For recording observations on, the percentage of plant mortality caused by soil arthropods will be calculated from the total number of plants and plants injured by soil arthropods at 30, 45, 65 and 90 days after sowing. The damaged plants will be removed following each count. From these data, per cent plant mortality due to soil arthropods will be calculated. At the time of harvest, total number of pods and pods damaged by soil arthropods will be also counted from five randomly selected plants at harvest in each net plot. At the time of harvest, pod as well as dry fodder yield will be recorded from the net plot area and convert in to kg per ha.

13.2.4 Yield and Economics

With a view to ascertain the effect of various biopesticides on the groundnut pod yield, the crop will be harvested from each net plot and weighed separately. The harvested pod yield will be converted into kg per hectare. The per cent increase yield over control will be also calculated by using the following formula mentioned below given by Pradhan (1969).

$$\text{Yield increased (\%)} = \frac{T - C}{C} \times 100$$

Where,

T = Yield of respective treatment (kg/ha)

C = Yield from control (kg/ha)

Economics of all the treatments will be worked out by considering the price of groundnut seed, cost of biopesticides used and labour charges for spraying of biopesticides. Incremental cost benefit ratio (ICBR) will be also work out to compare the economics of various treatments.

$$\text{Incremental Cost Benefit Ratio (ICBR)} = \frac{\text{Net realization (₹/ha)}}{\text{Total cost of natural inputs (₹/ha)}}$$

13.2.5 Observations to be recorded

1. Per cent plant mortality
2. Pod and haulm yield (kg/ha)

13.3 Efficacy of different insecticides against soil arthropods

13.3.1 Details of field experiment

1.	**Location of experiment**	:	Oilseeds Research Station, Junagadh Agricultural University, Manavadar
2.	**Season and year**	:	*Kharif*, 2026 and 2027
3.	**Crop and variety**	:	Groundnut, GG-23
4.	**Gross plot size**	:	2.25 m × 5.0 m
5.	**Net plot size**	:	1.35 m × 4.0 m
6.	**Spacing**	:	45.0 cm × 10.0 cm
7.	**Seed rate**	:	100 kg/ha
8.	**Fertilizer**	:	12.5: 25: 50 NPK kg/ha
9.	**Design**	:	Randomized Block Design
10.	**Treatments**	:	12
11.	**Replications**	:	3

Table 2. Treatment details of insecticides

Sr. No.	Treatment detail	Method of Application	Quantity required (kg or l/ha)	g or ml a.i./ha
1.	Chlorantraniliprole 0.40 % GR	Broadcasting	0.80	18.75
2.	Chlorpyrifos 20 EC	Drenching	5.00	225
3.	Carbofuran 3G	Broadcasting	0.66	200
4.	Clothianidin 50 WDG	Drenching	0.50	250
5.	Fipronil 40 % + Imidacloprid 40 % WG	Drenching	1.20	300
6.	Quinalphos 25 EC	Drenching	2.00	250
7.	Fipronil 5 % SC	Drenching	4.00	1500
8.	Thiamethoxam 75 % SG	Drenching	0.15	125
9.	Fipronil 0.30 % GR	Broadcasting	0.66	100
10.	Clothianidin 0.5 % GR	Broadcasting	2.40	60
11.	Imidacloprid 30.50 % SC	Drenching	0.80	75
12.	Untreated Control	-	-	-

13.3.2 Applications of insecticides

Groundnut crop will be raised by adopting recommended agronomical practices in *Kharif*, 2026-27. Treatment wise application of insecticides will be given by using knapsack sprayer. The control plots will be drenched with water. Drenching fluid will

be prepared by mixing measured quantity of water and insecticides. Drenching will be carried out for water soluble insecticides, at the initiation of pest. For soil drenching treatments, 1000 lit per ha of water will be used and subsequent two application will be done at 15 days interval. For broadcasting of granular insecticides recommended dose of insecticide mixed with the sand particles and applied in the crop in the furrow by hand in broadcasting manner and after that light irrigation will be applied.

13.3.3 Method of recording observations

The method of recording observations by following the same method as described under **13.2.3**.

13.3.4 Yield and Economics

The yield and economics will be worked as per **13.2.4**.

13.3.5 Observations to be recorded

1. Per cent plant mortality
2. Pod and haulm yield (kg/ha)

13.4 Entomopathogenic fungi enriched with organic amendments against soil arthropods

13.4.1 Details of the field experiment

1.	**Location of experiment**	:	Oilseeds Research Station, Junagadh Agricultural University, Manavadar
2.	**Season and year**	:	*Kharif*, 2026 and 2027
3.	**Crop and variety**	:	Groundnut, GG-23
4.	**Gross plot size**	:	2.25 m × 5.0 m
5.	**Net plot size**	:	1.35 m × 4.0 m
6.	**Spacing**	:	45.0 cm × 10.0 cm
7.	**Seed rate**	:	100 kg/ha
8.	**Fertilizer**	:	12.5: 25: 50 NPK kg/ha
9.	**Design**	:	Randomized Block Design
10.	**Treatments**	:	13
12.	**Replications**	:	3

Table 3. Treatment details

Sr. no	Treatments
1.	Neem cake @ 500 kg/ha

2.	Neem cake @ 500 kg /ha + *Beauveria bassiana* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
3.	Neem cake @ 500 kg /ha + *Metarhizium anisopliae* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
4.	Poultry manure @ 500 kg /ha
5.	Poultry manure @ 500 kg /ha + *Beauveria bassiana* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
6.	Poultry manure @ 500 kg /ha + *Metarhizium anisopliae* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
7.	Vermicompost @ 500 kg /ha
8.	Vermicompost @ 500 kg /ha + *Beauveria bassiana* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
9.	Vermicompost @ 500 kg /ha + *Metarhizium anisopliae* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
10.	Castor cake @ 500 kg /ha
11.	Castor cake @ 500 kg /ha + *Beauveria bassiana* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
12.	Castor cake @ 500 kg /ha + *Metarhizium anisopliae* 1.15 WP (1×10^8 cfu/g, min) @ 2 kg/ha
13.	Untreated control

13.4.2 Method of application

Groundnut crop will be raised by adopting recommended agronomical practices in *Kharif*, 2026-27. The calculated amount entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* mixed with different organic amendments 20 days prior to land preparation (Table 3). The treatments will be applied at the time of land preparation.

13.4.3 Method of recording observations

Observation on total number of plants and plants damaged by soil arthropods will be recorded at 30, 45, 65 and 90 days after sowing from net plot. The damaged plants will be removed after each count. From these data, percent plant mortality due to soil arthropods will be computed. Yield will be also recorded at harvest and economics of treatments will be calculated.

13.4.4 Yield and Economics

The yield and economics will be worked as per **13.2.4**

13.4.5 Observations to be recorded

1. Per cent plant mortality

2. Pod and haulm yield (kg/ha)

13.5 Biochemical basis of resistance in different groundnut varieties/cultivars about infestation of soil arthropods

13.5.1 Details of field experiment

1.	**Location of experiment**	:	Oilseeds Research Station, Junagadh Agricultural University, Manavadar
2.	**Season and year**	:	*Kharif*, 2026 and 2027
3.	**Crop and variety**	:	Groundnut
4.	**Plot size**	:	0.90 m × 4.0 m
5.	**Spacing**	:	45.0 cm × 10.0 cm
6.	**Replications**	:	2
7.	**Treatments**	:	15 available genotypes/varieties provided by Research Scientist, Main Oilseeds Research Station, JAU, Junagadh
8.	**Design**	:	Randomized Block Design

13.5.2 Methodology

To study screening of different groundnut genotypes against soil arthropods the experiment will be conducted during *Kharif* 2026 and 2027. Two lines of each genotypes/variety will be grown with a spacing of 45.00 cm × 10.00 cm and the same will be followed for other replication. All other agronomical practices will be followed as per the scientific recommendations and genotypes/varieties under the experiment will be free from insecticides throughout the season. The observation on soil arthropods will be recorded from randomly selected ten plants from each genotypes/variety at weekly intervals. The data obtained will be subjected to statistical analysis for assessment of least susceptible genotypes/varieties against soil arthropods in groundnut. Groundnut yield will be recorded in each genotypes/variety.

The different groundnut genotypes/varieties will be grouped into six categories of resistance to soil arthropods *viz.,* highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible based on infestation soil arthropods. For this purpose, the mean value of individual genotype ($\bar{X}i$) will be compared with the mean value of all genotypes ($\bar{X}$) and standard deviation (SD). The retransformed data will be used for the computation of $\bar{X}$, $\bar{X}i$ and SD in case of this

parameter. The scale used for categorizing different genotypes/varieties will be under (Avula, 2024).

Categorization of groundnut genotypes/varieties will be under

Category of resistance	Scale for resistance
Highly resistant	$\bar{X}i \leq (\bar{X} - 2SD)$
Resistant	$(\bar{X} - SD) \geq \bar{X}i > (\bar{X} - 2SD)$
Moderately resistant	$\bar{X} \geq \bar{X}i > (\bar{X} - SD)$
Moderately susceptible	$\bar{X} < \bar{X}i \leq (\bar{X} + SD)$
Susceptible	$(\bar{X} + SD) < \bar{X}i \leq (\bar{X} + 2SD)$
Highly susceptible	$\bar{X}i > (\bar{X} + 2SD)$

The different groundnut genotypes/varieties will be grouped into total nine categories total plants from each growing will be uprooted and the damage will be assessed by the total number of pods damaged by soil arthropods. The data obtained and pod and haulm yield (kg/ha) and per cent pod damages will be worked out and will be categories as per 1 to 9 scale (Rohilla R. H. 2004) and extent of pod scarification on 1 to 9 scale as mentioned below:

Table 4: Rating scale on the basis of per cent pod damage of soil arthropods

Sr. No.	Index scale	% Pods damaged
1.	1	0
2.	2	1 to 10
3.	3	11 to 20
4.	4	21 to 30
5.	5	31 to 40
6.	6	41 to 50
7.	7	51 to 60
8.	8	61 to 75
9.	9	76 to 100

13.5.3 Observations to be recorded

1. Per cent pod damage
2. Pod and haulm yield (kg/ha)

13.5.4 Biochemical characters of different groundnut genotypes/varieties

To study the biochemical characters *viz.,* total phenol (Bray and Thorpe, 1954), total sugar (Nelson, 1944), free amino acid (Moore and Stein, 1984), protein (Lowry *et al*., 1951) and chlorophyll content by SPAD meter will be measured to see their relationship with incidence of soil arthropods. The observations on the above characters will be recorded from each genotypes/variety by selecting ten plants randomly at 45-60

days after sowing. Root, peg formation and pod samples will be taken from different replication of each genotypes/variety after infestation and subsequently analysed for biochemical changes. The simple correlation will be carried out to study the relationship between soil arthropods populations and biochemical characters of groundnut.

13.5.5 Observations to be recorded

1. Total phenol (mg/g)
2. Total sugar (mg/g)
3. Free amino acid (mg/g)
4. Protein content (mg/g)
5. Chlorophyll content (SPAD)

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Signature of Student | Signature of Major Guide

(Parmar Dhruv N.) | **(K. P. BARAIYA)**

CERTIFICATE

This is to certify that **PARMAR DHRUVKUMAR NARANBHAI (Registration No.: 1010125016)** has made an oral presentation of the synopsis of research project entitled **"Succession, mechanism of resistance and management of soil arthropods in groundnut"** in **Department of Entomology, College of Agriculture, JAU, Junagadh** dated **23/03/2026** in the presence of advisory committee members, other faculty members and post graduate students. The student has incorporated all the suggestions.

Signature of major guide and the members of the advisory committee

GUIDE and MEMBERS	NAME	DESIGNATION and ADDRESS	SIGNATURE
Major Guide (Entomology)	Dr. K. P. Baraiya	Senior Scientist and Head Krushi Vigyan Kendra JAU, Jamnagar	
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